



# Missouri Department of Natural Resources

## State Parks Macroinvertebrate Inventory Study

**Bryant Creek State Park  
Douglas County, Missouri**

**2021**

**Prepared for:  
Missouri Department of Natural Resources  
Division of State Parks  
Natural Resource Management Program**

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## **1.0 Introduction**

At the request of the Missouri Department of Natural Resources' (**MoDNR**) Missouri State Parks, the Environmental Services Program's (**ESP**) Water Quality Monitoring Section (**WQMS**) conducted an aquatic macroinvertebrate inventory study at Bryant Creek State Park (**BCSP**). Macroinvertebrates and surface water samples were collected at two stations within the park during the spring of 2021 to supplement samples that were collected in 2020 and presented in a previous report ([MoDNR 2021](#)).

### **1.1 Study Area/Justification**

Bryant Creek State Park is located in southern Douglas County and covers a total of 2,917 acres ([MoDNR 2017](#)). The park has steep terrain carved out by many streams and springs. A total of 4.9 miles of perennial or intermittent streams flow through the park. The largest water feature is Bryant Creek, which borders 1.7 miles of the northern edge of the park. Bryant Creek is classified as an Ozark small warm-water river and was identified in the 2005 and 2015 Missouri State Wildlife Action Plans as a state Conservation Opportunity Area ([MoDNR 2017](#)). Highway N splits BCSP into northern and southern sections. Streams within the north section are tributaries to Bryant Creek, and streams in the south section are tributaries to Spring Creek. Spring Creek is also a tributary to Bryant Creek. Land cover within BCSP consists of 93.7 percent deciduous forest, 2.2 percent developed, 2.0 percent mixed forest, 1.4 percent hay/pasture, 0.5 percent evergreen forest, and 0.1 percent herbaceous cover. BCSP is in the Jacks Fork Aquatic Ecological System Type, which has geology predominantly consisting of cherty dolomites and sandstone from the Gasconade and Roubidoux formations ([Sowa et al. 2005](#)). Sandstone ledges are also present in the park, providing overhangs and wet-weather waterfalls.

The Fiscal Year 2021 Quality Assurance Project Plan ([MoDNR 2020a](#)) describes the rationale for acquisition of BCSP and for the biological inventories conducted on the property.

[BCSP was] acquired by Natural Resources Damage and Recovery funds, to compensate for injuries to groundwater in Missouri. Their management priorities are to restore and preserve native ecosystems in the surface- and groundwater recharge areas of their respective high-value streams, to improve water quality. Understanding the native flora and fauna is fundamental to assessing needs and measuring success, and several biological inventories are underway to provide that baseline reference. This project will provide the initial inventory and baseline for select representative aquatic communities within the park.

### **1.2 Objectives**

- 1) Inventory and examine the aquatic macroinvertebrate communities within selected stream reaches in BCSP.
- 2) Collect and assess physicochemical water samples within selected stream reaches in BCSP.

## **2.0 Methods**

Joe Chilton, Dave Michaelson, and Carl Wakefield of MoDNR's WQMS collected samples for this study. Cadie Olson, also of WQMS, performed all land use analyses, calculated the biological metrics, and created the charts and figures for this report. All staff followed standard operating procedures (SOPs) established for the collection and analysis of macroinvertebrate, flow, and physiochemical water data.

During the previous macroinvertebrate inventory study ([MoDNR 2021](#)), Missouri Stream Team volunteers collected qualitative samples from three stations in BCSP to supplement the taxa lists generated via standard semi-quantitative WQMS biological assessment sampling methods. No volunteer samples were collected from BCSP in 2021.

## **2.1 Station Descriptions**

Two stations were sampled within the boundaries of BCSP during this phase of the inventory study ([Figure 1](#)). In addition, Bryant Creek was sampled separately in spring 2021 approximately 4.5 river miles upstream of the BCSP boundary for a biological assessment study. Samples collected at this location should provide an accurate representation of the macroinvertebrate fauna in Bryant Creek along the BCSP northeastern boundary. The macroinvertebrate community of headwater streams sampled within the park was compared to four reference quality headwater streams (HWREF) within the Ozark/White Ecological Drainage Unit (EDU). Larger streams, such as Bryant Creek, tend to have more available habitat and higher macroinvertebrate taxa richness than smaller streams. The smaller headwater streams used for comparison may show a closer representation of the aquatic community expected in study streams. These HWREF stations were sampled in the spring of 2015 and 2016.

### **2.1.1 Bryant Creek State Park Sampling Stations**

#### Pike Hollow

The legal description was NW ¼ Sec. 30, T. 25 N., R. 13 W. Geographic coordinates for the upstream boundary of the station were Universal Transverse Mercator (UTM) zone 15, 552165 Easting, 4076035 Northing.

Pike Hollow is located within the north section of BCSP. Samples were collected downstream of a small spring that contributed to flow from upstream. Pike Hollow is part of the Missouri Use Designation Dataset and is classified as a Class C waterbody. A class C stream is one that may cease flow in dry periods but maintains permanent pools that support aquatic life ([MoDNR 2019g](#)). On the day in which samples were collected, surface flow ceased in Pike Hollow as it passed through a reach of gravel and cobble a few hundred yards downstream of the coordinates listed above. We did not follow the dry stream channel to its confluence with Major Hollow to observe whether surface flow resumed.

The Pike Hollow sampling location was accessed from a ridgetop path that made its way from the BCSP house on County Road N-337D eastward through the forest. Pike Hollow lies at the base of a steep descent (roughly 25 percent grade) from the ridgetop. Pike Hollow was narrow, rarely more than 6 feet wide, and shallow with occasional pools in the sampling reach. Rootmat

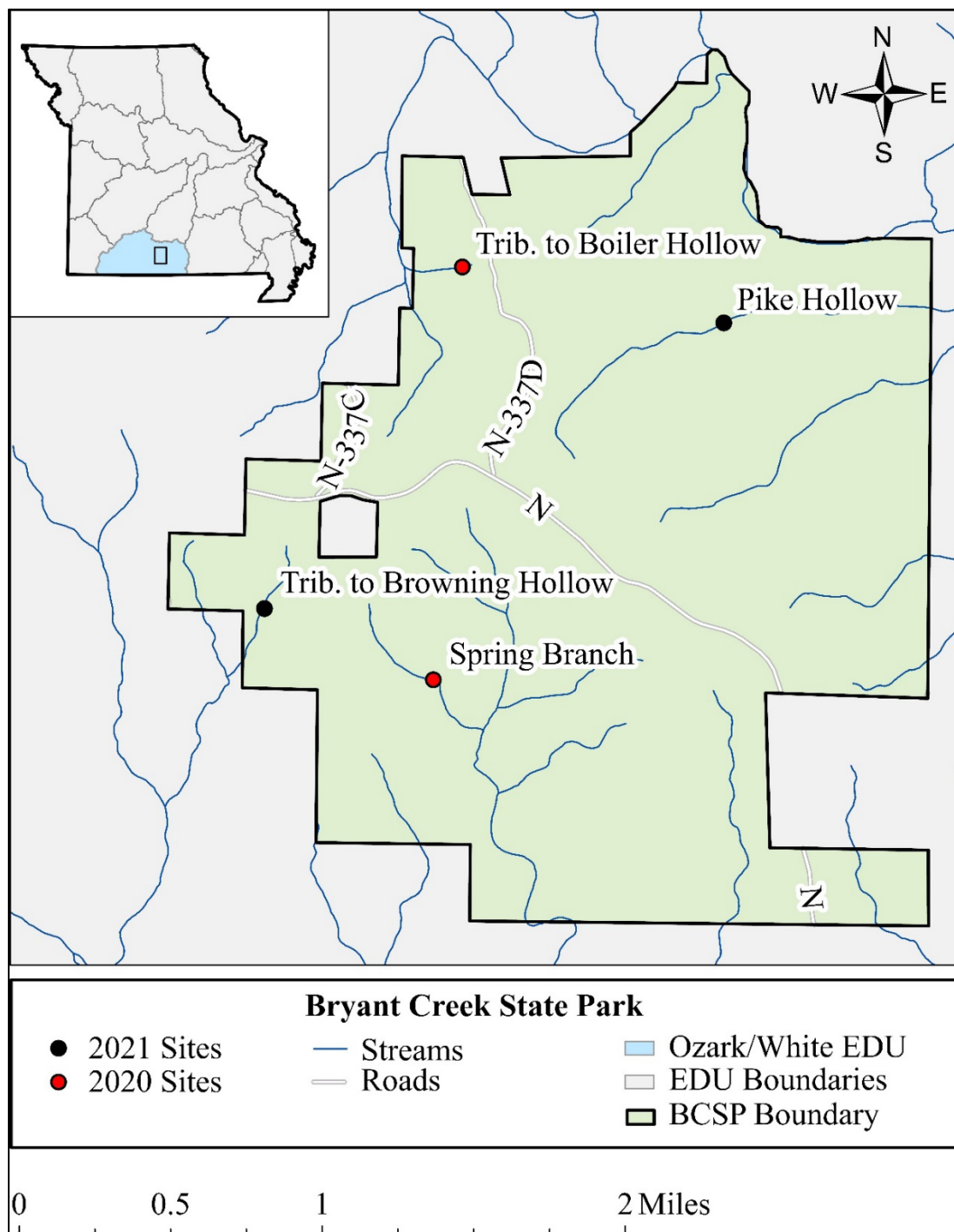


Figure 1. Map of Bryant Creek State Park sampling locations.

habitat was scarce and of marginal quality for macroinvertebrate colonization, a condition common to small headwater streams prone to flashiness and intermittent drying. The two remaining habitats sampled, coarse substrate and nonflow, were abundant.

#### Unnamed Tributary to Browning Hollow

The legal description was SE ¼ Sec. 26, T. 25 N., R. 14 W. Geographic coordinates for the downstream boundary of the station were UTM zone 15, 549726 Easting, 4074520 Northing.

Samples were collected upstream of a power line right-of-way near the eastern boundary of BCSP's south section. The relief of the area surrounding Tributary to Browning Hollow was much less than that of Pike Hollow. Tributary to Browning Hollow, however, was similarly narrow compared to Pike Hollow and had similar physical habitat attributes. Unlike Pike Hollow, Tributary to Browning Hollow had surface flow throughout the sampling reach and downstream. Despite this observation, Tributary to Browning Hollow is not classified under the Missouri Use Designation Dataset. As such, this site is not listed as a classified stream.

### **2.1.2 Mainstem Bryant Creek Sampling Station**

Bryant Creek Station #2535\_23.27 (not pictured in Figure 1): Legal description was NW ¼ Sec. 10, T. 25 N., R. 14 W. Geographic coordinates for the upstream boundary of the station were UTM zone 15, 547082 Easting, 4080532 Northing. Samples were collected downstream of the County Road 329 crossing at the Rippee Conservation Area, which is about 3.5 miles northwest of BCSP's northeast corner boundary (4.5 river miles). A total of six macroinvertebrate samples were collected by WQMS staff between 1999 and 2021 at this location. Only sample data from spring 2021 are presented in this report.

## **2.2 Study Timing**

Macroinvertebrate and physicochemical water quality samples were collected at BCSP on March 31, 2021. Bryant Creek Station 2535\_23.27 was sampled on April 14, 2021.

## **2.3 Land Use**

Percent land use type and area were calculated using ArcGIS® 10.7.1 software by Esri. ArcGIS®. Land use type was determined using a 2019 layer from the National Land Cover Database (NLCD) ([United States Geological Survey \[USGS\] 2019](#)). Percent land use type and area were analyzed for each station's estimated catchment-basin. In addition, percent land use and area were determined for the BCSP boundary and the Ozark/White EDU.

## **2.4 Macroinvertebrate Collection and Analysis**

A standardized macroinvertebrate sample collection and analysis procedure was followed as described in the *Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure* ([MoDNR 2019a](#)) for riffle/pool streams. At each station, sampling occurred in three habitat types: riffle or run habitat containing coarse substrate, depositional substrate in non-flowing water, and rootmat.

Macroinvertebrate communities were analyzed using the following metrics: taxa richness (TR), Ephemeroptera/Plecoptera/Trichoptera taxa (EPTT), biotic index (BI), Shannon Diversity Index (SDI), and percent dominant macroinvertebrate families and taxa. These metrics were calculated for individual stations and for all stations collectively within the park. Comparisons of the macroinvertebrate community between stations in BCSP were also made. The following is an explanation of the biological metrics used in this report.

- **Taxa Richness (TR)**

Reflects the health of the community through a measurement of the number of taxa present. In general, the total number of taxa increases with improving water quality, habitat diversity, and habitat suitability. TR is calculated by counting all taxa from the laboratory subsampling effort plus those found during a final search for large or rare taxa that were not encountered during random subsampling.

- **Ephemeroptera, Plecoptera, and Trichoptera Taxa (EPTT)**

This value summarizes taxa richness within the insect taxonomic orders that are generally considered to be pollution sensitive (Ephemeroptera [mayflies], Plecoptera [stoneflies], and Trichoptera [caddisflies]). The EPTT index generally increases with higher water quality.

- **Biotic Index (BI)**

This value is a means of describing organic pollution tolerance (e.g. wastewater constituents) of individual taxa within the macroinvertebrate communities expressed as a single value between 0 and 10, with 0 being the most sensitive and 10 being the most tolerant. The BI value for a macroinvertebrate sample is expressed as a weighted mean of all individuals identified in the sample.

- **Shannon Diversity Index (SDI)**

This index is a measure of community composition that takes into account both richness and evenness. It is assumed that a more diverse community is a healthier community. SDI increases as the number of taxa increases and as the distribution of individuals among those taxa is more evenly distributed.

Metric values were calculated for BCSP stations and all Ozark/White EDU HWREF streams. Metric values were averaged across all HWREF streams, and the 25<sup>th</sup> percentiles were recorded. For metric values that decrease with impairment (TR, EPTT, and SDI), any value above the 25<sup>th</sup> percentile is considered comparable to HWREF streams. For metric values that increase with impairment (BI), any value below the 75<sup>th</sup> percentile is considered comparable to HWREF conditions ([MoDNR 2019a](#)). These quartile values are used to evaluate biological integrity in biological assessment studies, but because the BCSP stations were considerably smaller than HWREF systems, comparisons to these criteria should be loosely interpreted and viewed as informational.



To provide more insight into the composition of the macroinvertebrate assemblages, additional analyses were conducted. These analyses include percent taxa by BI range; percent of samples made up by the orders Ephemeroptera, Plecoptera, and Trichoptera; and percent of each of the top five dominant taxa. Percent sensitive taxa was also calculated for each sample to show the relative percentage of taxa ranging from sensitive to tolerant as measured from groupings of BI value ranges.

Bryant Creek is one of three wadeable/perennial biological criteria reference (**BIOREF**) streams in the Ozark/White EDU. Its status as a BIORREF stream indicates that it is among the best available and least disturbed streams in the EDU. Samples collected from Bryant Creek have been used to calculate criteria to evaluate the biological integrity of similar-sized streams in the Ozark/White EDU. The sample collected at Bryant Creek 2535\_23.27 was compared to BIORREF criteria.

## **2.5 Physicochemical Data Collection and Analysis**

### **2.5.1 *In situ* Water Quality Measurements**

*In situ* water quality measurements were collected during each sampling event. Field measurements included water temperature (°C) ([MoDNR 2018d](#)), dissolved oxygen (mg/L) ([MoDNR 2019c](#)), conductivity (µS/cm) ([MoDNR 2018e](#)), and pH ([MoDNR 2018c](#)).

### **2.5.2 Water Chemistry**

Surface water grab samples were collected and returned to ESP for analyses. Turbidity (NTU) ([MoDNR 2018b](#)) was measured and recorded in the ESP WQMS biology laboratory. Water samples were analyzed by ESP's Chemical Analysis Section for non-filterable residue, chloride, sulfate, hardness (calculated with dissolved calcium and magnesium), total phosphorus, ammonia as N, nitrate+nitrite as N, total nitrogen, and dissolved metals (arsenic, barium, cadmium, calcium, copper, lead, magnesium, nickel, and zinc). Procedures outlined in *Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations* ([MoDNR 2018a](#)) and *Field Sheet and Chain-of-Custody Record* ([MoDNR 2019b](#)) were followed when collecting water quality samples.

### **2.5.3 Discharge**

Stream velocity was measured at each station using a SonTek FlowTracker2 Handheld-ADV (Acoustic Doppler Velocimeter). Discharge was determined per the methods in SOP MDNR-ESP-113, *Flow Measurement in Open Channels* ([MoDNR 2020b](#)).

## **2.6 Quality Assurance/Quality Control (QA/QC)**

### **2.6.1 Field Meters**

All field meters used to collect water quality parameters were maintained in accordance with SOP MDNR-ESP-213, *Quality Control Procedures for Checking Water Quality Field Instruments* ([MoDNR 2016](#)).

### **2.6.2 Biological Samples**

Steps to assure accuracy of organism removal from sample debris were performed consistent with those methods described in the *Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure* ([MoDNR 2019a](#)). Macroinvertebrates found in samples were identified to taxonomic levels in SOP MDNR-ESP-209, *Taxonomic Levels for Macroinvertebrate Identification* ([MoDNR 2019d](#)).

### **2.6.3 Biological Data Entry**

All macroinvertebrate data were entered into the WQMS macroinvertebrate database consistent with Standard Operating Procedure MDNR-ESP-214, *Quality Control Procedures for Data Processing* ([MoDNR 2019f](#)).

### **2.6.4 Duplicate Sample Collection**

Duplicate samples are obtained from the same location at essentially the same time as the true sample following the same procedures in accordance with *Quality Assurance/Quality Control for Environmental Data Collection* ([MDNR 2019e](#)). True samples and duplicate samples are analyzed for the same set of parameters; however, they are analyzed and reported independently. A duplicate is used to assess the precision associated with sampling methodology, sample heterogeneity, and analytical procedures ([MDNR 2019e](#)). No duplicate samples were collected at BCSP during this study.

## **3.0 Results**

### **3.1 Land Use**

Comparison of land use between BCSP and the Ozark/White EDU showed BCSP contained far more forested land cover than the rest of the EDU ([Table 1](#)). Land use in BCSP consisted of 96 percent forested, 2 percent developed/impervious, and 1 percent hay/pasture. The forested area was primarily composed of deciduous forest ([Figure 2](#)). Developed/impervious areas mostly consisted of roads/driveways and a small house on BCSP's north section. A relatively small area (<0.1 mi<sup>2</sup>) of pasture/hay land use is around this house and a nearby barn. Since Missouri State Parks acquired the property, there have been no farming practices taking place. Sample station catchments within the park were small, with Pike Hollow and Tributary to Browning Hollow having catchment areas of 0.49 mi<sup>2</sup> and 0.12 mi<sup>2</sup>, respectively. Both BCSP sampling stations' catchment-basins were entirely within park boundaries. The Tributary to Browning Hollow catchment land use was 100 percent forested, and the Pike Hollow catchment land use was mostly forested with small amounts of hay/pasture and developed/impervious surfaces.

Table 1. Percent land cover for each station's catchment, Bryant Creek State Park, and Ozark/White EDU\*.

| Station/<br>Boundary       | Open<br>Water | Developed/<br>Impervious | Forested | Scrub/<br>Herbaceous | Hay/<br>Pasture | Cultivated<br>Crops | Wetlands | Area<br>(miles <sup>2</sup> ) |
|----------------------------|---------------|--------------------------|----------|----------------------|-----------------|---------------------|----------|-------------------------------|
| Pike Hollow                | 0             | 1.63                     | 97.21    | 0                    | 1.15            | 0                   | 0        | 0.49                          |
| Trib. Browning<br>Hollow   | 0             | 0                        | 100      | 0                    | 0               | 0                   | 0        | 0.12                          |
| Bryant Creek<br>2535 23.27 | 1.0           | 0.64                     | 72.53    | 5.45                 | 19.08           | 0.55                | 0.01     | 191.4                         |
| BCSP Boundary              | 0.02          | 2.26                     | 96.28    | 0.11                 | 1.31            | 0                   | 0.02     | 4.56                          |
| Ozark/White<br>EDU         | 1.90          | 7.61                     | 56.17    | 2.19                 | 31.68           | 0.11                | 0.10     | 4732                          |

\*Barren land use was included in the 2019 NLCD but excluded from this table. No barren land occurred within BCSP, and less than 0.25 percent was present in the Ozark/White EDU.

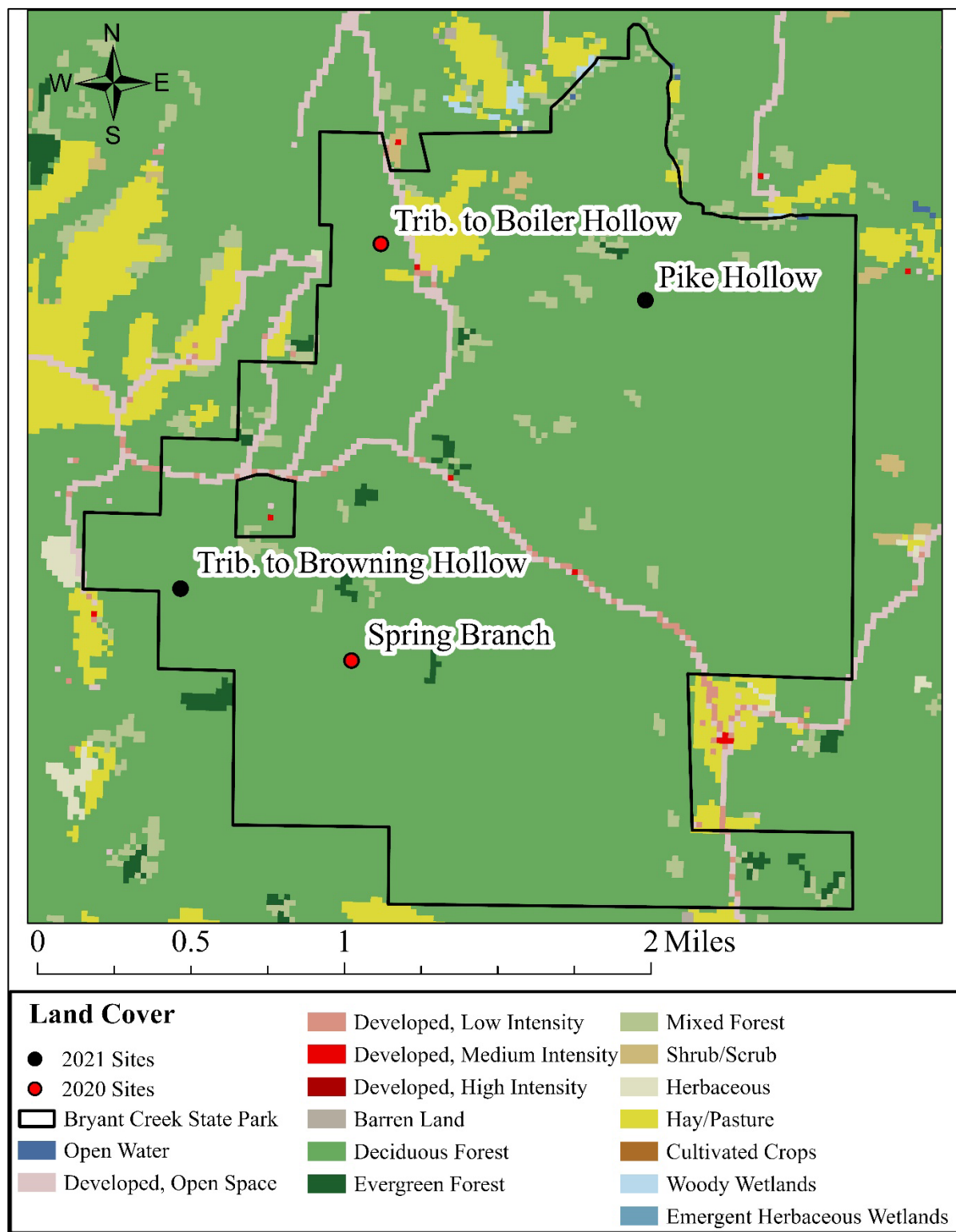


Figure 2. Land use within Bryant Creek State Park and surrounding area.

## 3.2 Biological Survey

### 3.2.1 Biological Metrics

Spring 2021 biological metric values for Pike Hollow and Tributary to Browning Hollow are presented in [Table 2](#). Pike Hollow and Tributary to Browning Hollow are compared to the EDU's HWREF streams. Bryant Creek Station 2535\_23.27 is presented separately in [Table 3](#) and compared to BIOREF criteria due to its much larger size. The 25<sup>th</sup> percentile for each biological metric is presented in Tables 2 and 3, with the exception of BI. For the BI metric, the 75<sup>th</sup> percentile value is presented to reflect this metric's inverse scoring hierarchy (i.e. sensitive taxa have lower BI values than tolerant taxa).

Pike Hollow had fewer total taxa and EPT taxa than Tributary to Browning Hollow, despite having a larger watershed size and being a classified waterbody. The Pike Hollow macroinvertebrate community, as gauged by the BI and SDI values, was more tolerant and less diverse than Tributary to Browning Hollow. Compared to Ozark/White EDU HWREF streams, biological metrics for both BCSP streams sampled in 2021 were below the 25<sup>th</sup> percentile, with the exception of the Tributary to Browning Hollow SDI value. The Tributary to Browning Hollow sample also had a lower BI value than the HWREF, indicating a more sensitive overall macroinvertebrate community.

Table 2. Metric values for BCSP stations and Ozark/White EDU candidate headwater streams.

| Station                                               | TR | EPTT | BI  | SDI  |
|-------------------------------------------------------|----|------|-----|------|
| Pike Hollow                                           | 54 | 16   | 5.8 | 2.33 |
| Trib. Browning Hollow                                 | 77 | 21   | 4.0 | 3.51 |
| Ozark/White EDU Headwater Candidate Reference Streams |    |      |     |      |
| Average                                               | 85 | 27   | 4.7 | 3.36 |
| 25th percentile*                                      | 81 | 27   | 4.9 | 3.35 |

\*the 75<sup>th</sup> percentile is presented for the BI metric

Bryant Creek biological metrics all exceeded the 25<sup>th</sup> percentile values of BIOREF streams, and the BI value was below the 75<sup>th</sup> percentile. These metric values indicate that the Bryant Creek macroinvertebrate community is comparable to or better than the suite of data collected from the best available streams in the Ozark/White EDU.

Table 3. Metric values for Bryant Creek and Ozark/White EDU biological criteria reference streams.

| Station                                       | TR  | EPTT | BI  | SDI  |
|-----------------------------------------------|-----|------|-----|------|
| Bryant Creek 2535_23.27                       | 99  | 38   | 4.5 | 3.65 |
| Ozark/White EDU Biocriteria Reference Streams |     |      |     |      |
| Average                                       | 103 | 34   | 4.3 | 3.46 |
| 25th percentile*                              | 95  | 31   | 4.7 | 3.26 |

\*the 75<sup>th</sup> percentile is presented for the BI metric

### 3.2.2 Percent Sensitive Taxa

The percentage of sensitive taxa (BI<2.5) was variable among stations (Figure 3). Sensitive taxa accounted for less than half of the Pike Hollow sample, but Bryant Creek and the average among BIOREF streams were roughly similar. Tributary to Browning Hollow had the highest percentage of sensitive taxa among samples considered here, but it also had a higher percentage of tolerant taxa. Pike Hollow had a much larger proportion of its sample in the moderately tolerant range (BI 7.5 - 9.0) than the remaining samples or the mean among HWREF sites. Tributary to Browning Hollow and Bryant Creek samples were similar to one another with respect to proportions of sensitive taxa. The Bryant Creek sample had nearly identical proportions of sensitivity groupings compared to the average among wadeable/perennial BIOREF samples.

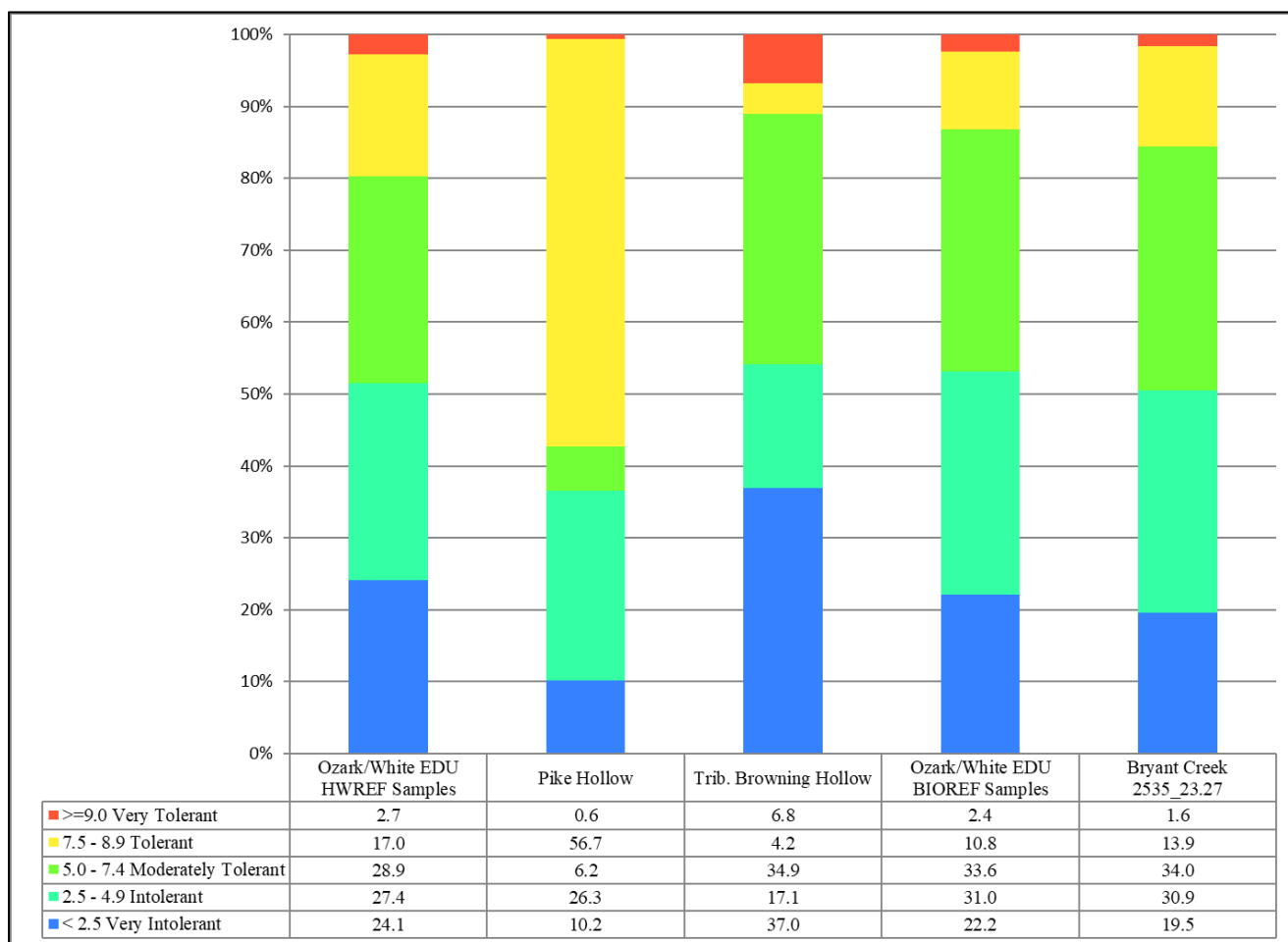


Figure 3. Percent of taxa by biotic index range for state parks inventory study sampling stations.

### **3.2.3 Macroinvertebrate Community Composition**

Macroinvertebrate community composition summary statistics for Pike Hollow, Tributary to Browning Hollow, and the average among HWREF samples are presented in [Table 4](#). Bryant Creek 2535\_23.27 and average BIOREF summary statistics are presented in [Table 5](#).

#### Bryant Creek State Park Samples

The macroinvertebrate community compositions of the two BCSP headwater streams were very different from one another ([Table 4](#)). Pike Hollow was dominated by aquatic sow bugs (Isopoda), true flies (Diptera), and scuds (Amphipoda). EPT taxa were rare in Pike Hollow compared to Tributary to Browning Hollow and HWREF streams, and no EPT taxa were among the dominant taxa. With respect to EPT taxa, the Tributary to Browning Hollow community was more similar to HWREF streams, with each of the three orders occurring in similar percentages. In Tributary to Browning Hollow, amphipods were present in much lower abundance than either the Pike Hollow or HWREF samples, and isopods were absent. Riffle beetles (Elmidae) were absent from the Tributary to Browning Hollow sample, but they were among the dominant families at Pike Hollow and present in low numbers among HWREF sites.

#### Bryant Creek Station 2535\_23.27

The spring 2021 Bryant Creek 2535\_23.27 sample had a similar pattern of abundance for EPT taxa compared to the average among BIOREF samples, with the exception that stoneflies accounted for a higher percentage of the Bryant Creek sample ([Table 5](#)). Mayflies and true flies made up similar percentages between the Bryant Creek and BIOREF samples with beetles, stoneflies, and caddisflies also being among the top five dominant orders for both data sets. Like the smaller streams of BCSP and HWREF samples, non-biting midges (Chironomidae) were also abundant among the Bryant Creek and BIOREF samples. Unlike the smaller streams, however, Bryant Creek and the BIOREF samples had riffle beetle, mayfly, and stonefly families in high abundance.

### **3.3 Physiochemical Water Sample Analysis**

All physiochemical parameters analyzed for samples collected in BCSP and Bryant Creek were in compliance with Missouri's Water Quality Standards (WQS, [MoDNR 2019g](#)). Of the nine dissolved metals tested, five were below detectable concentrations at one or both BCSP sites ([Table 6](#)). Dissolved metals samples were not collected at Bryant Creek Station 2535\_23.27. Dissolved copper and zinc were present in higher concentrations in the Pike Hollow sample, but dissolved barium, calcium, and magnesium were higher in the Tributary to Browning Hollow sample. Even when present in detectable concentrations, no metals were close to their respective hardness-dependent chronic toxicity criteria (Tables A1 and A2 in the WQS [[MoDNR 2019g](#)]).

Table 4. Spring 2021 Bryant Creek State Park macroinvertebrate sample summary statistics.

| Metrics -Station              | Pike Hollow | Trib.<br>Browning<br>Hollow | Average<br>HWREF |
|-------------------------------|-------------|-----------------------------|------------------|
| Sample Number                 | 21082       | 21083                       | N/A              |
| Sample Date                   | 3/31/2021   | 3/31/2021                   | N/A              |
|                               |             |                             |                  |
| % EPT                         |             |                             |                  |
| % Ephemeroptera               | 3.2         | 23.4                        | 17.9             |
| % Plecoptera                  | 6.7         | 15.9                        | 19.4             |
| % Trichoptera                 | 6.5         | 9.8                         | 8.1              |
|                               |             |                             |                  |
| % Dominant Orders             |             |                             |                  |
| Isopoda                       | 40.3        | 0.0                         | 16.4             |
| Diptera                       | 20.4        | 36.6                        | 33.7             |
| Amphipoda                     | 13.0        | 0.1                         | 4.5              |
| Coleoptera                    | 6.9         | 7.0                         | 2.8              |
| Plecoptera                    | 6.7         | 15.9                        | 19.7             |
| Trichoptera                   | 6.5         | 9.8                         | 8.1              |
| Ephemeroptera                 | 3.2         | 23.4                        | 17.9             |
|                               |             |                             |                  |
| % Dominant Families           |             |                             |                  |
| Asellidae                     | 40.3        | 0.0                         | 16.4             |
| Chironomidae                  | 16.8        | 31.1                        | 26.6             |
| Crangonyctidae                | 13.0        | 0.1                         | 4.9              |
| Elmidae                       | 6.5         | 0.0                         | 1.4              |
| Nemouridae                    | 5.6         | 7.0                         | 7.1              |
| Dytiscidae                    | 3.0         | 6.5                         | 0.3              |
| Leptophlebiidae               | 0.2         | 9.0                         | 7.5              |
| Lepidostomatidae              | 0.0         | 6.1                         | 0.3              |
|                               |             |                             |                  |
| % Dominant Taxa               |             |                             |                  |
| <i>Lirceus</i>                | 40.3        | 0.0                         | 7.0              |
| <i>Crangonyx</i>              | 13.0        | 0.0                         | 2.3              |
| <i>Parametriocnemus</i>       | 10.7        | 3.0                         | 0.6              |
| <i>Optioservus sandersoni</i> | 6.5         | 0.0                         | 0.6              |
| <i>Amphinemura</i>            | 5.6         | 7.1                         | 8.8              |
| <i>Micropsectra</i>           | 0.8         | 7.6                         | 0.6              |
| <i>Heterotrissocladius</i>    | 0.3         | 5.3                         | <0.1             |
| <i>Lepidostoma</i>            | 0.0         | 6.1                         | 0.3              |
| <i>Paraleptophlebia</i>       | 0.0         | 9.0                         | 1.7              |
| <i>Siphonurus</i>             | 0.0         | 5.3                         | 0.1              |



Table 5. Spring 2021 Bryant Creek Station 2535\_23.27 macroinvertebrate sample summary statistics.

| Metrics -Station               | Bryant Cr.<br>2535_23.27 | Average<br>BIOREF |
|--------------------------------|--------------------------|-------------------|
| Sample Number                  | 21091                    | N/A               |
| Sample Date                    | 4/14/2021                | N/A               |
|                                |                          |                   |
| % EPT                          |                          |                   |
| % Ephemeroptera                | 34.3                     | 30.6              |
| % Plecoptera                   | 10.0                     | 5.2               |
| % Trichoptera                  | 3.2                      | 3.5               |
|                                |                          |                   |
| % Dominant Orders              |                          |                   |
| Ephemeroptera                  | 34.3                     | 30.6              |
| Diptera                        | 33.1                     | 32.9              |
| Coleoptera                     | 15.3                     | 7.5               |
| Plecoptera                     | 10.0                     | 5.2               |
| Trichoptera                    | 3.2                      | 3.5               |
|                                |                          |                   |
| % Dominant Families            |                          |                   |
| Chironomidae                   | 28.6                     | 29.8              |
| Elmidae                        | 14.7                     | 5.3               |
| Heptageniidae                  | 10.6                     | 11.7              |
| Caenidae                       | 10.3                     | 4.2               |
| Ephemerellidae                 | 5.5                      | 9.4               |
| Perlidae                       | 5.5                      | 1.7               |
|                                |                          |                   |
| % Dominant Taxa                |                          |                   |
| <i>Caenis latipennis</i>       | 10.3                     | 2.5               |
| <i>Optioservus sandersoni</i>  | 7.7                      | 3.8               |
| <i>Cricotopus/Orthocladius</i> | 7.3                      | 6.7               |
| <i>Perlesta</i>                | 5.5                      | 1.0               |
| <i>Stenelmis</i>               | 4.6                      | 0.3               |
| <i>Elimia</i>                  | 0.2                      | 12.2              |
| <i>Leucrocuta</i>              | 0.1                      | 6.0               |
| <i>Ephemerella invaria</i>     | 1.8                      | 5.4               |

Table 6. Physiochemical variables at state parks inventory study sampling stations.

| Variable-Station                      | Pike Hollow              | Trib. Browning Hollow | Bryant Creek 2535_23.27 |
|---------------------------------------|--------------------------|-----------------------|-------------------------|
| Sample Number                         | 21000423                 | 21000424              | 21000389                |
| Sample Date                           | 3/31/2021                | 3/31/2021             | 4/14/2021               |
| Sample Time                           | 0950                     | 1145                  | 1545                    |
| Ammonia as N (mg/L)                   | <0.2 <sup>a</sup>        | <0.2 <sup>a</sup>     | <0.2 <sup>a</sup>       |
| Chloride (mg/L)                       | <1.5 <sup>a</sup>        | <1.5 <sup>a</sup>     | 2.69                    |
| Conductivity (µS/cm)                  | 349                      | 349                   | 387                     |
| Discharge (cfs)                       | 0.6                      | 0.3                   | 200                     |
| Dissolved Oxygen (mg/L)               | 10.82                    | 10.89                 | 11.45                   |
| Hardness as CaCO <sub>3</sub> (mg/L)  | 117                      | 190                   | 215                     |
| Nitrate + Nitrite as N (mg/L)         | 0.012                    | <0.008 <sup>a</sup>   | <b>0.291</b>            |
| Non-filterable Residue (mg/L)         | <5.0 <sup>a</sup>        | <5.0 <sup>a</sup>     | <5.0 <sup>a</sup>       |
| pH (standard units)                   | 7.7                      | 8.3                   | 8.6                     |
| Temperature (°C)                      | 10.6                     | 12.0                  | 15.6                    |
| Total Nitrogen (mg/L)                 | 0.02                     | 0.05                  | 0.27                    |
| Total Phosphorus (mg/L)               | <b>0.033<sup>c</sup></b> | <0.005 <sup>a</sup>   | <b>0.014</b>            |
| Sulfate (mg/L)                        | <3.5 <sup>a</sup>        | 4.07 <sup>b</sup>     | 6.93 <sup>d</sup>       |
| Turbidity (NTU)                       | <b>1.77</b>              | <b>2.84</b>           | 0.69                    |
| Arsenic - Dissolved (µg/L)            | <0.5 <sup>a</sup>        | <0.5 <sup>a</sup>     | *                       |
| Barium – Dissolved (µg/L)             | 19.4                     | 25.7                  | *                       |
| Cadmium – Dissolved (µg/L)            | <0.1 <sup>a</sup>        | <0.1 <sup>a</sup>     | *                       |
| Calcium – Dissolved ( <b>mg</b> /L)   | 23.6                     | 39.0                  | *                       |
| Copper - Dissolved (µg/L)             | 1.02                     | <0.5 <sup>a</sup>     | *                       |
| Lead – Dissolved (µg/L)               | <0.5 <sup>a</sup>        | <0.5 <sup>a</sup>     | *                       |
| Magnesium – Dissolved ( <b>mg</b> /L) | 14.0                     | 22.5                  | *                       |
| Nickel - Dissolved (µg/L)             | <0.5 <sup>a</sup>        | <0.5 <sup>a</sup>     | *                       |
| Zinc - Dissolved (µg/L)               | 7.05                     | 1.48                  | *                       |
| Calcium - Total Recoverable (mg/L)    | --                       | --                    | 44.4                    |
| Magnesium - Total Recoverable (mg/L)  | --                       | --                    | 25.2                    |

<sup>a</sup>Below laboratory detectable concentrations

<sup>b</sup>Estimated value - Result between method detection limit (**MDL**) and practical quantitation limit (**PQL**)

<sup>c</sup>Analyte present in blank at >1/2 of reported value

<sup>d</sup>Estimated value - matrix interference

\*Bryant Creek Station 2535\_23.27 was sampled as a separate study for which dissolved metals analyses were not required.

Values in bold represent exceedances of USEPA's recommended nutrient concentrations (NO<sub>3</sub>+NO<sub>2</sub>-N = 0.239 mg/L; TN = 0.397 mg/L; TP = 0.007 mg/L; and turbidity = 1.425 NTU).

Because there are currently no nutrient standards for streams and rivers in Missouri, nutrient concentrations were compared to recommended values from the United States Environmental Protection Agency (USEPA). Recommended values for nutrients and turbidity in the Ozarks Highlands ecoregion are as follows: 0.239 mg/L nitrate + nitrite, 0.379 mg/L total nitrogen, 0.007 mg/L total phosphorus, and 1.425 NTU turbidity (USEPA 2000). The total phosphorus concentration and the turbidity level in Pike Hollow were slightly higher than the recommended values, but no other nutrients had exceedances (Table 6). Although all nutrient values were below USEPA recommended concentrations at Tributary to Browning Hollow, turbidity was slightly higher than the recommended level. Bryant Creek Station 2535\_23.27 had exceedances for total phosphorus and nitrate + nitrite as N, but turbidity was below the recommended value.

## **4.0 Discussion**

### **4.1 Land Use**

As mentioned in the previous BCSP biological inventory report (MoDNR 2021), BCSP has a higher proportion of forested land use than the Ozark/White EDU as a whole. With the exception of a small amount of impervious surface and hay/pasture around the park residence, land use in the Pike Hollow watershed was exclusively forest. The Tributary to Browning Hollow watershed had no other land use than forest. Forested watersheds tend to provide better rainwater infiltration, less storm water runoff, and better water quality in streams than other land uses (Archer et al. 2015, Lenat and Crawford 1994). These factors play an important role in protecting the biological integrity of aquatic communities (Harding et al. 1988, Lenat and Crawford 1994, Roth et al. 1996).

The watersheds of Pike Hollow and Tributary to Browning Hollow are entirely within the bounds of BCSP. Continued land use management to promote a diverse and healthy forest in the park will help to ensure the biological integrity of BCSP streams and headwater systems. Forested watersheds are also important for protecting the water quality of small springs in the park, whose recharge areas are likely within the BCSP boundary.

Bryant Creek Station 2535\_23.27 also has a relatively high percentage of forested land cover (over 70 percent), is located within a stream reach designated among Outstanding State Resource Waters (MoDNR 2019g), and is within one of the three BIOREF reaches in the Ozark/White EDU. These designations indicate that this stream reach has land use and water quality features that make it among the best available stream resources in the EDU.

### **4.2 Biological Survey**

#### **4.2.1 Biological Metrics**

With the exception of the Tributary to Browning Hollow SDI, biological metric values for both samples were below the respective quartile values calculated for HWREF streams. As pointed out in the previous BCSP inventory study (MoDNR 2021), however, the streams sampled for this inventory project are considerably smaller than the HWREF streams. The average HWREF discharge measurement, for example, is 3.4 cfs compared to 0.6 cfs and 0.3 cfs for the BCSP locations.

Although both BCSP samples had lower biological metric values than the quartile values of HWREF streams, they were not alarmingly different than the perennial headwater systems. Of the seven samples used to calculate average and quartile values in [Table 2](#), one had TR and EPTT values equal to Pike Hollow. The Tributary to Browning Hollow sample had TR and EPTT values that were comparable to or, in one instance, exceeded HWREF quartile values. Although these comparisons were not made for assessment purposes, they do indicate that, despite being very small, these BCSP streams have good taxonomic richness and EPTT richness for their sizes, especially in the case of Tributary to Browning Hollow, which is an unclassified stream.

Bryant Creek Station 2535\_23.27 attained the highest possible biological assessment score when compared to Ozark/White EDU wadeable/perennial BIOREF criteria. TR, EPT, and SDI values all exceeded their respective quartile values, and BI was below the 75<sup>th</sup> percentile. These metrics indicate that the macroinvertebrate community of Bryant Creek was at least as diverse and sensitive to pollutants compared to other BIOREF samples collected in the Ozark/White EDU. Given that the spring 2021 sample was collected in a reach of Bryant Creek that is not only a biocriteria reference stream but also an Outstanding State Resource Water ([MoDNR 2019g](#)), it was expected to have performed well. Some BIOREF streams across the state have declined in quality over time due to such factors as land use changes (MoDNR unpublished data), so it is encouraging that the macroinvertebrate community in Bryant Creek continues to do well.

#### 4.2.2 Percent Sensitive Taxa

Tributary to Browning Hollow had a higher percentage of very sensitive taxa ( $BI < 2.5$ ) than BIOREF streams in the Ozark/White EDU and a lower percentage of very tolerant taxa ( $BI \geq 9.0$ ). By comparison, Pike Hollow had a much lower percentage of very sensitive taxa but also a lower percentage of very tolerant taxa. The majority of the Pike Hollow sample was in the moderately tolerant range ( $BI 7.5-8.9$ ), which corresponds to the dominant taxa *Lirceus* and *Crangonyx* having BI values of 7.7 and 8.0, respectively.

The sensitivity categories for Bryant Creek 2535\_23.27 were extremely close to the percentages calculated for BIOREF streams. Although Bryant Creek is an Ozark/White BIOREF stream, and past samples collected at this site are part of the aggregate BIOREF data set, the sample collected in 2021 was evaluated independently. As such, the similarity among sensitivity categories was not due to a violation of data independence. Considerable annual variability occurs naturally in aquatic systems, and even reference streams can yield poor results in any given year. In spring 2021, it appears that the watershed land use and antecedent weather and flow conditions were ideal for the Bryant Creek macroinvertebrate community.

#### 4.2.3 Macroinvertebrate Community Composition

##### Bryant Creek State Park Samples

Pike Hollow was dominated by the isopod *Lirceus* and, to a lesser extent, the amphipod *Crangonyx*. Together these genera accounted for over half of the individuals in the Pike Hollow sample. A similar observation made for the Tributary to Boiler Hollow sample collected in 2020 was used to suggest that it is an intermittent stream ([MoDNR 2021](#)). Isopods and amphipods,

such as *Lirceus* and *Crangonyx*, are often found in streams subject to periodic drying, and non-insect taxa can dominate these systems due to their ability, at least in the case of *Lirceus*, to inhabit the hyporheic zone ([Kelso and Entekin 2018](#)). However, in addition to high densities of isopods and amphipods, the presence of other macroinvertebrate taxa suggests the presence of permanent water in Pike Hollow. In small streams, permanent water can be isolated pools, the hyporheic zone, or both. Based on the observation that Pike Hollow transitions to subsurface flow downstream of the reach sampled, there is almost certainly a great deal of interaction between surface water and shallow groundwater, which provides refuge during low flow periods. Ringed Crayfish (*Faxonius neglectus*) were present in all three habitats sampled. In addition to macroinvertebrates, we also incidentally collected Southern Redbelly Dace (*Chrosomus erythrogaster*) in kick samples and released them unharmed. Within Missouri, Southern Redbelly Dace tend to inhabit small creeks and spring branches with permanent flow, primarily in the Ozarks ([Pflieger 1997](#)). The presence of both crayfish and fish suggests that despite being very small, Pike Hollow has sufficient flow to maintain enough wetted habitat to sustain a limited, but permanent aquatic community.

Despite having a smaller watershed and slightly less flow, Tributary to Browning Hollow not only had a much higher number of macroinvertebrate taxa than Pike Hollow but also a higher number of EPT taxa, higher SDI, and a lower BI value. Whereas isopods and amphipods were the dominant taxa in Pike Hollow, there were no isopods and only a single amphipod collected at Tributary to Browning Hollow. Diptera (primarily chironomids) was the dominant taxonomic order, followed by Ephemeroptera and Plecoptera. Unlike Pike Hollow, the Tributary to Browning Hollow sample had a more even distribution of taxa, with no single taxon being overwhelmingly dominant. There was little overlap among dominant taxa for the two streams, indicating two very different macroinvertebrate communities. The relative composition of the two macroinvertebrate communities sampled suggest that differences may be due at least partly to differences in base flow regime, habitat, and food resources.

Spothand Crayfish (*Faxonius punctimanus*) were collected in the nonflow and rootmat habitats of Tributary to Browning Hollow. The presence of crayfish, certain dragonflies, and blind amphipods (discussed in the Notable Taxa section below) indicate that Tributary to Browning Hollow also has permanently flowing water or at least refugia in isolated pools or the shallow groundwater to sustain a year-round aquatic community.

#### Bryant Creek Station 2535\_23.27

Similar to past BIOREF samples, Bryant Creek was dominated by mayflies and true flies (mostly Chironomidae). These two taxonomic orders were present in nearly identical abundance, followed by beetles and stoneflies. Although Bryant Creek 2535\_23.27 had similar numbers of total taxa and EPT taxa compared to BIOREF samples, the relative abundance of beetles (mostly riffle beetles in the family Elmidae) and stoneflies was much higher in Bryant Creek. The tolerance values of EPT taxa and elmids were variable, with representation from extremely sensitive to moderately tolerant. There were, however, few individuals classified as very tolerant. Overall, the spring 2021 Bryant Creek sample was generally similar to the average among BIOREF samples. Macroinvertebrates can have patchy distributions and can vary from year to

year, so differences observed between Bryant Creek and the suite of BIOREF streams is a common occurrence.

#### 4.2.4 Notable Taxa

Several rarely-collected or otherwise notable taxa were collected in 2020 during the previous BCSP inventory study ([MoDNR 2021](#)). Many of these taxa occurred in habitats that are not typically sampled by WQMS biologists, such as headwater spring branches and seeps. No new state records were found in BCSP spring 2021 samples, but there were several taxa that had unique life history characteristics or are rarely collected by WQMS staff that are highlighted below.

##### Pike Hollow

Although the Pike Hollow sample reach was immediately downstream from a spring branch, we did not encounter any taxa of particular note. Because the Pike Hollow spring branch was so small, we considered our standard kicknet sampling method to be too invasive for the habitat available, so we limited our efforts to the Pike Hollow mainstem. By sampling Pike Hollow at the spring branch confluence and farther downstream, it was our expectation that we would encounter unique taxa similar to those encountered in the spring of 2020. Two insects were collected in Pike Hollow that are rarely collected by WQMS staff. The phantom crane fly *Ptychoptera* was collected in the previous inventory study ([MoDNR 2021](#)), and it was found in Pike Hollow during this study. Of over 3,000 samples collected by WQMS, *Ptychoptera* has occurred in only five samples, two of which were in BCSP. Similarly, the caddisfly *Diplectrona* is also rarely encountered, being found in only 13 WQMS samples, two of which were in BCSP.

##### Tributary to Browning Hollow

Most of the taxa collected in Tributary to Browning Hollow were common, with the exception of a blind amphipod and one species of aquatic worm. The amphipod *Stygobromus* inhabits shallow groundwater, seeps, and cave habitats ([Holsinger 1978](#)). Although not a rare taxon, *Stygobromus* is notable due to its ability to live at the interface of surface and subsurface environments. *Stygobromus* is also unique in that it is one of only a few taxa collected in streams that are clearly adapted to life underground by being unpigmented and eyeless.

*Tasserkidrilus superiorensis* has been collected in only 15 samples collected by WQMS over the span of nearly 30 years. Based on WQMS samples, *T. superiorensis* is widely distributed, occurring from Caldwell and Grundy counties in north-central Missouri southward to Ripley County. The type locality for this species is Lake Superior ([Brinkhurst and Cook 1966](#) [as cited in [World Register of Marine Species](#)]), and its occurrence has been documented in Russia ([Brinkhurst 1984](#) [as cited in [Kathman and Brinkhurst 1999](#)]). *Tasserkidrilus superiorensis* is certainly not a rare species with a limited range or requiring unique habitats, but it is rarely encountered in WQMS samples and was singled out solely for that distinction.

The dragonfly *Cordulegaster obliqua* (whose common name is the “Arrowhead Spiketail”) has a similar distinction as *T. superiorensis* in that, despite being widely dispersed ([Trial 2005](#)), it is infrequently collected by WQMS. Larvae bury themselves in fine sediments of small woodland

streams, with only their eyes and antennae exposed, lying in wait to ambush passing prey ([Needham et al. 2014](#)). The presence of *Cordulegaster* species is also noteworthy because they have semivoltine life cycles, requiring more than one year to mature from egg to adult ([Burcher and Smock 2002](#)). Depending on the species and the latitude or altitude of their occurrence, individuals in the genus *Cordulegaster* may spend two to five years in their aquatic larval phase before emerging as adults ([Ferrerias-Romero and Corbet 1999](#)). Given their life history strategy, *C. obliqua* is another taxon, along with the fish and crayfish observed/collected in BCSP, that requires access to permanent water.

The lack of state records or few unique taxa in BCSP samples does not imply the streams sampled in 2021 are lacking in quality. For example, both sites had an impressive diversity of stonefly taxa, a group of aquatic insects that is particularly sensitive to pollutants, as well as other sensitive mayfly and caddisfly taxa. For the size of their watersheds, these two BCSP streams had robust and diverse macroinvertebrate communities that rival those of larger high-quality Ozark streams.

#### **4.3 Physiochemical Water Sample Analysis**

##### Bryant Creek State Park Samples

*In situ* physicochemical water quality measurements were generally similar between the two BCSP stations. Discharge at Pike Hollow was twice that of Tributary to Browning Hollow, which likely was a result of its larger catchment size and the contribution of a small spring. Both sites had very low flow (0.3 cfs and 0.6 cfs), however, so it is questionable whether the absolute difference between the two sites affected water quality results. Conductivity and dissolved oxygen were equal or nearly equal between sites. Dissolved oxygen was 100 percent of saturation at Pike Hollow and 104 percent of saturation at Tributary to Browning Hollow. Temperature, pH, and turbidity all were higher at Tributary to Browning Hollow. The cooler temperature at Pike Hollow could have been the result of the earlier sampling time; its location in a steep valley, which may limit daily sunlight exposure; the influx of spring water; or a combination of all three factors. Although turbidity was higher at Tributary to Browning Hollow, the difference was slight and likely not indicative of water quality issues.

The lower pH of Pike Hollow (7.7 versus 8.3 standard units) was a relatively small difference but interesting nonetheless, given that the pH scale is logarithmic. The catchments of both locations are entirely within BCSP boundaries, so there is likely nothing anthropogenic causing the difference. In natural settings, pH can be affected by such factors as aquatic plant photosynthesis, the weakly acidic water resulting from percolation through decaying organic matter (e.g. leaf litter), and the buffering capacity of a watershed's geology ([Wetzel 1983](#)). For example, watersheds dominated by limestone/dolomite geology have greater buffering capacity than those with igneous or sandstone geology. Calcium, magnesium, and hardness levels all were lower at Pike Hollow, where the pH was slightly more acidic. This pH difference is mentioned mostly as a point of curiosity, however, because the pH levels for both sites were well within the acceptable range specified in Missouri's WQS ([MoDNR 2019g](#)).



All water quality parameters collected in BCSP samples met Missouri's WQS ([MoDNR 2019g](#)). Dissolved metals concentrations were below detectable concentrations or were well below their respective hardness-dependent chronic concentrations. With the exception of total nitrogen, nutrient concentrations tended to be slightly higher at Pike Hollow, and the total phosphorus concentration exceeded the USEPA recommended value ([USEPA 2000](#)). For samples collected within BCSP, this was the only nutrient parameter in exceedance. The previous BCSP inventory report noted higher nutrient concentrations in BCSP 2, an unnamed tributary to Boiler Hollow ([MoDNR 2021](#)). The catchment of BCSP 2 included the park residence, the impervious surface of County Road N-337D, and the hay/pasture area around the residence. Although Pike Hollow also had some of this same land use, there was much less of its catchment attributed to impervious or hay/pasture and a higher percentage of forest. It is possible that these small areas of impervious surface and hay/pasture led to Pike Hollow having slightly higher nutrient concentrations than Tributary to Browning Hollow, where the catchment was 100 percent forest. Although turbidity was slightly higher than USEPA recommended values at both BCSP sites, it was unlikely to be an ecological problem. Nutrient and turbidity values recommended by USEPA represent the 25<sup>th</sup> percentile of streams within the region and, as such, are among the lowest in the Ozarks ecoregion ([USEPA 2000](#)).

#### Bryant Creek Station 23\_27 Sample

With the exception of turbidity, all Bryant Creek *in situ* water quality measurements were higher than BCSP samples. Discharge at the MDC Rippee Conservation Area was 200 cfs, which was likely near the median flow for the spring season based on a rough proportional watershed size comparison with Bryant Creek at a USGS gaging station approximately 35 river miles downstream. The median April 14 discharge at USGS gage #07058000 is 578 cfs. This gage has a watershed size of 570 mi<sup>2</sup> and a period of record dating back to 1944. By comparison, Bryant Creek at the Rippee Conservation Area has a watershed size of 191.4 mi<sup>2</sup>.

Bryant Creek conductivity was slightly higher than either of the BCSP samples, as was the chloride concentration. Although the chloride concentration was very low in Bryant Creek, it was below detectable concentrations at both BCSP sites. Chloride, along with sulfate and other dissolved ions, tend to lead to higher conductivity values, which is a measure of water's ability to conduct electricity. Bryant Creek temperature and dissolved oxygen both were higher than the BCSP streams. At 118 percent, dissolved oxygen at Bryant Creek was supersaturated, and temperature was nearly 4°C higher than the warmest BCSP site. Bryant Creek was sampled on a warmer day and later in the day two weeks after BCSP. Temperature and dissolved oxygen tend to peak in the afternoon hours as solar radiation and photosynthesis each have their greatest cumulative effects. Bryant Creek pH was slightly higher than the BCSP sites, which could be due to greater buffering capacity in the larger watershed or the later afternoon sampling time. Photosynthesis of aquatic plants during the day and respiration at night are factors that affect not only dissolved oxygen, but also lead to diurnal fluctuations in which pH is highest in the afternoon and lowest near sunrise ([Wetzel 1983](#)).

All Bryant Creek water quality parameters samples met Missouri's WQS ([MoDNR 2019g](#)). Nutrient concentrations tended to be higher in Bryant Creek than the BCSP samples, with total



phosphorus and nitrate+nitrite as nitrogen exceeding USEPA recommended values ([USEPA 2000](#)). Although the Bryant Creek total phosphorus concentration was above USEPA recommendations, it was slightly lower than the Pike Hollow level. Turbidity was well below the USEPA recommended value of 1.425 NTU and lower than either BCSP sample. Higher nutrient concentrations in the Bryant Creek sample, compared to the BCSP sites, is likely due to the larger watershed and more diverse land use of Bryant Creek, which includes hay/pasture and a small amount of cultivated crops. Despite some nutrient concentrations being higher than USEPA recommended levels, they did not appear to negatively affect the macroinvertebrate community.

## **5.0 Conclusion**

Bryant Creek State Park has diverse headwater aquatic systems, including high gradient streams and waterfalls as well as springs and losing sections in which surface flow disappears into the stream bed. Along the park's northeastern boundary are steep bluffs that border Bryant Creek, an Outstanding State Resource Water farther upstream, which provides even more aquatic resources adjacent to the park.

In the span of just over two years, the WQMS and Missouri Stream Team volunteers found 163 distinct macroinvertebrate taxa from six headwater streams and one spring branch at BCSP. Techniques included standard multi-habitat WQMS kick net sampling protocols as well as volunteers using small aquarium dip nets for sampling small, fragile environments. To supplement the taxa list even farther, volunteers also collected the adult life stages of aquatic insects by sampling streamside vegetation with an insect sweep net. Of the 99 taxa identified in the 2021 Bryant Creek sample, 59 were unique to Bryant Creek. In total, including all WQMS and volunteer samples, there are at least 222 aquatic macroinvertebrate taxa in and around the park. This number is a conservative count; additional sampling conducted in other watersheds of the park and in other times of year would undoubtedly raise this number. Nevertheless, 163 taxa from headwater systems, each of whose watersheds is a fraction of a square mile, represents an impressive aquatic community.

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Appendix A  
Bryant Creek State Park Macroinvertebrate Taxa Lists  
Spring 2021

Semi-quantitative kick-net WQMS collections of macroinvertebrates from **Pike Hollow**.

Habitats: CS = coarse substrate, NF = nonflow, RM = rootmat. \* = taxon found in sample during final laboratory “large/rare” search.

| ORDER: Taxa            | Habitat |     |    |
|------------------------|---------|-----|----|
|                        | CS      | NF  | RM |
| <b>"HYDRACARINA"</b>   |         |     |    |
| Acarina                | 2       | 1   | 1  |
| <b>AMPHIPODA</b>       |         |     |    |
| Crangonyx              | 77      | 65  | 36 |
| <b>BASOMMATOPHORA</b>  |         |     |    |
| Physella               | *       | *   | 1  |
| <b>COLEOPTERA</b>      |         |     |    |
| Ectopria nervosa       | 1       | 1   |    |
| Heterosternuta         |         | 2   |    |
| Optioservus sandersoni | 80      | 4   | 5  |
| Paracymus              |         |     | 1  |
| <b>DECAPODA</b>        |         |     |    |
| Faxonius neglectus     | *       | 2   | *  |
| <b>DIPTERA</b>         |         |     |    |
| Caloparyphus           |         | 1   |    |
| Ceratopogoninae        | 7       | 2   |    |
| Chelifera              | 17      | 7   | 2  |
| Chironomidae           | 2       | 7   |    |
| Cladotanytarsus        |         |     | 2  |
| Diptera                |         | 1   |    |
| Dixa                   |         |     | 2  |
| Eukiefferiella         | 1       |     | 1  |
| Heterotrissocladius    |         | 2   | 2  |
| Hexatoma               | *       | *   |    |
| Micropsectra           | 3       | 8   |    |
| Parametriocnemus       | 4       | 141 | 1  |
| Polypedilum tritum     |         | 2   |    |
| Pseudolimnophila       | 2       | 6   | 1  |
| Pseudorthocladius      | 1       | 6   | 1  |
| Psilometriocnemus      | 3       | 11  |    |
| Ptychoptera            |         | *   |    |

Pike Hollow, continued.

| <b>ORDER: Taxa</b>    | <b>Habitat</b> |           |           |
|-----------------------|----------------|-----------|-----------|
|                       | <b>CS</b>      | <b>NF</b> | <b>RM</b> |
| Stempellina           | 10             | 7         |           |
| Tabanus               |                | 1         |           |
| Thienemannimyia grp   |                | 1         |           |
| Tipula                | *              |           | *         |
| Tvetenia bavarica grp | 10             |           | 2         |
| <b>EPHEMEROPTERA</b>  |                |           |           |
| Acentrella            | 20             |           | 2         |
| Diphetor              | 16             |           | 3         |
| Leptophlebia          |                | 1         | 2         |
| <b>HEMIPTERA</b>      |                |           |           |
| Microvelia            |                |           | 3         |
| <b>ISOPODA</b>        |                |           |           |
| Lirceus               | 291            | 59        | 200       |
| <b>MEGALOPTERA</b>    |                |           |           |
| Sialis                |                | *         |           |
| <b>ODONATA</b>        |                |           |           |
| Cordulegaster obliqua |                | *         |           |
| <b>PLECOPTERA</b>     |                |           |           |
| Alloperla             | 9              |           |           |
| Amphinemura           | 53             | 3         | 20        |
| Clioperla clio        | *              |           |           |
| Isoperla              | 1              |           |           |
| Leuctridae            | 4              |           | 1         |
| <b>TRICHOPTERA</b>    |                |           |           |
| Agapetus              | 35             | 3         | 1         |
| Brachycentrus         |                |           | 9         |
| Diplectrona           | 4              |           | 3         |
| Ironoquia             |                |           | 1         |
| Leptoceridae          | 2              |           |           |
| Pycnopsyche           | 1              | 7         | 7         |
| Rhyacophila           | 10             |           |           |
| Wormaldia             | 5              | 1         |           |
| <b>TRICLADIDA</b>     |                |           |           |
| Planariidae           | 17             | 2         | 6         |
| <b>TUBIFICIDA</b>     |                |           |           |
| Enchytraeidae         | 2              |           |           |
| Tubificinae           |                | 3         |           |



Semi-quantitative kick-net WQMS collections of macroinvertebrates from **Tributary to Browning Hollow**. Habitats: CS = coarse substrate, NF = nonflow, RM = rootmat. \* = taxon found in sample during final laboratory "large/rare" search.

| ORDER: Taxa             | Habitat |    |    |
|-------------------------|---------|----|----|
|                         | CS      | NF | RM |
| <b>"HYDRACARINA"</b>    |         |    |    |
| Acarina                 |         |    | 4  |
| <b>AMPHIPODA</b>        |         |    |    |
| Stygobromus             |         | 1  |    |
| <b>BASOMMATOPHORA</b>   |         |    |    |
| Physella                | 4       | 1  | 12 |
| <b>COLEOPTERA</b>       |         |    |    |
| Agabus                  | 6       | 4  | 3  |
| Dytiscidae              | 1       | 14 | 1  |
| Ectopria nervosa        |         |    | 2  |
| Helichus fastigiatus    | 3       |    |    |
| Heterosternuta          | 1       |    |    |
| <b>DECAPODA</b>         |         |    |    |
| Faxonius punctimanus    |         | *  | *  |
| <b>DIPTERA</b>          |         |    |    |
| Caloparyphus            | 4       |    |    |
| Cardiocladius           |         |    | 1  |
| Ceratopogoninae         |         | 6  |    |
| Chaetocladius           | 2       |    |    |
| Chironomidae            |         | 1  | 2  |
| Chrysops                | 1       | 2  |    |
| Corynoneura             |         | 1  |    |
| Cricotopus/Orthocladius | 44      | 3  | 5  |
| Dicrotendipes           | 1       |    |    |
| Diptera                 | 1       | 1  |    |
| Dixa                    |         |    | 2  |
| Dixella                 |         |    | 17 |
| Ephydriidae             | 1       | 1  |    |
| Eukiefferiella          | 1       |    | 1  |
| Forcipomyiinae          | 1       |    |    |
| Hemerodromia            | 1       |    |    |
| Heterotrissocladius     | 8       | 43 | 4  |
| Hexatoma                | 1       |    |    |
| Krenopelopia            | 2       | 4  |    |
| Larsia                  | 3       | 25 |    |
| Limoniidae              |         |    | 1  |

Tributary to Browning Hollow, continued.

| <b>ORDER: Taxa</b>        | <b>Habitat</b> |           |           |
|---------------------------|----------------|-----------|-----------|
|                           | <b>CS</b>      | <b>NF</b> | <b>RM</b> |
| Micropsectra              | 39             | 22        | 19        |
| Microtendipes             | 3              | 2         |           |
| Natarsia                  |                | 1         |           |
| Orthocladius              | 1              |           |           |
| (Symposiocladius)         |                |           |           |
| Parametriocnemus          | 23             | 5         | 3         |
| Paratendipes              |                | 6         |           |
| Polypedilum scalaenum grp |                | 1         |           |
| Pseudolimnophila          | 14             |           | 3         |
| Rheocricotopus            |                | 1         |           |
| Stempellinella            | 3              |           | 1         |
| Stictochironomus          |                | 17        |           |
| Stilocladius              | 1              |           |           |
| Tanytarsus                | 7              | 1         |           |
| Thienemannimyia grp       | 11             |           | 1         |
| Zavrelimyia               |                | 5         | 2         |
| <b>EPHEMEROPTERA</b>      |                |           |           |
| Ameletus                  | 26             | 3         | 12        |
| Baetis                    | 2              |           |           |
| Dipheter                  | 33             |           | 13        |
| Paraleptophlebia          | 21             | 53        | 20        |
| Plauditus                 | 3              |           | 4         |
| Siphonurus                | 22             | 30        | 3         |
| <b>HEMIPTERA</b>          |                |           |           |
| Microvelia                |                |           | 6         |
| <b>MEGALOPTERA</b>        |                |           |           |
| Sialis                    |                | 2         |           |
| <b>ODONATA</b>            |                |           |           |
| Cordulegaster obliqua     | *              | *         | 2         |
| Gomphidae                 | 7              |           |           |
| Somatochlora              | 1              |           |           |
| <b>PLECOPTERA</b>         |                |           |           |
| Acroneuria                | 1              |           |           |
| Alloperla                 | 14             | 3         | 2         |
| Amphinemura               | 48             |           | 26        |
| Clioperla clio            | 1              | *         | 2         |
| Isoperla                  | 4              |           | 1         |
| Perlesta                  | 11             | 1         | 1         |
| Zealeuctra                | 50             |           | 2         |

Tributary to Browning Hollow, continued.

| <b>ORDER: Taxa</b>           | <b>Habitat</b> |           |           |
|------------------------------|----------------|-----------|-----------|
|                              | <b>CS</b>      | <b>NF</b> | <b>RM</b> |
| <b>TRICHOPTERA</b>           |                |           |           |
| Agapetus                     | 27             |           | 11        |
| Ironoquia                    | 1              | 3         | 6         |
| Lepidostoma                  | 32             | 4         | 28        |
| Plectrocnemia                | 3              | *         | 1         |
| Psychomyia                   | 5              |           |           |
| Pycnopsyche                  |                |           | *         |
| Rhyacophila                  | 2              |           |           |
| Wormaldia                    | 17             |           | 1         |
| <b>TRICLADIDA</b>            |                |           |           |
| Planariidae                  | 1              |           |           |
| <b>TUBIFICIDA</b>            |                |           |           |
| Enchytraeidae                |                | 1         |           |
| Limnodrilus hoffmeisteri     | 1              | 5         |           |
| Tasserkidrilus superiorensis | 1              |           | 1         |
| Tubificinae                  | 5              | 12        | 3         |
| <b>VENEROIDA</b>             |                |           |           |
| Pisidiidae                   |                | 5         | 1         |

Semi-quantitative kick-net WQMS collections of macroinvertebrates from **Bryant Creek Station 2535\_23.27** at Rippee Conservation Area. Habitats: CS = coarse substrate, NF = nonflow, RM = rootmat. \* = taxon found in sample during final laboratory “large/rare” search.

| <b>ORDER: Taxa</b>      | <b>Habitat</b> |           |           |
|-------------------------|----------------|-----------|-----------|
|                         | <b>CS</b>      | <b>NF</b> | <b>RM</b> |
| <b>"HYDRACARINA"</b>    |                |           |           |
| Acarina                 | 4              | 3         | 8         |
| <b>AMPHIPODA</b>        |                |           |           |
| Gammarus                | 1              |           |           |
| Hyaella azteca          |                |           | 9         |
| <b>BASOMMATOPHORA</b>   |                |           |           |
| Gyraulid                |                | 1         |           |
| <b>COLEOPTERA</b>       |                |           |           |
| Ancyronyx variegatus    |                |           | 3         |
| Dubiraphia              |                | 19        | 9         |
| Ectopria nervosa        |                |           | 1         |
| Macronychus glabratus   |                |           | 3         |
| Optioservus sandersoni  | 77             | 22        | 5         |
| Psephenus herricki      | 4              |           | 2         |
| Stenelmis               | 44             | 8         | 10        |
| <b>DECAPODA</b>         |                |           |           |
| Faxonius neglectus      | *              | *         | *         |
| <b>DIPTERA</b>          |                |           |           |
| Ablabesmyia             |                | 1         | 4         |
| Cardiocladius           | 4              |           |           |
| Ceratopogoninae         | 2              | 2         | 1         |
| Chironomidae            | 4              | 2         | 6         |
| Cladotanytarsus         | 1              | 53        | 3         |
| Clinocera               | 2              | 1         |           |
| Cricotopus/Orthocladius | 56             | 26        | 17        |
| Cryptochironomus        | 1              | 9         | 1         |
| Dicrotendipes           |                | 6         | 9         |
| Eukiefferiella          | 57             | 1         | 1         |
| Gonomyia                | 4              |           |           |
| Hemerodromia            | 13             | 2         | 4         |
| Hexatoma                | 2              | 2         |           |
| Micropsectra            | 6              | 1         | 2         |
| Nilothauma              |                | 1         |           |
| Parakiefferiella        |                | 9         |           |
| Paralauterborniella     |                | 2         |           |
| Paratanytarsus          |                |           | 3         |

Bryant Creek, continued.

| ORDER: Taxa              | Habitat |    |    |
|--------------------------|---------|----|----|
|                          | CS      | NF | RM |
| Paratendipes             |         |    | 1  |
| Phaenopsectra            |         | 2  | 1  |
| Polypedilum fallax grp   |         | 3  |    |
| Polypedilum flavum       | 22      | 10 | 2  |
| Potthastia               | 3       | 1  | 3  |
| Prosimulium              | 1       |    |    |
| Protoplasia fitchii      | *       |    |    |
| Rheotanytarsus           |         |    | 2  |
| Robackia                 | 1       |    |    |
| Simulium                 | 22      |    | 1  |
| Stempellina              |         | 1  |    |
| Stempellinella           |         | 4  |    |
| Synorthocladius          | 1       |    |    |
| Tabanus                  | 1       |    | 1  |
| Tanytarsus               | 2       | 8  | 8  |
| Thienemanniella          |         |    | 1  |
| Thienemannimyia grp      | 1       | 12 | 13 |
| <b>EPHEMEROPTERA</b>     |         |    |    |
| Acentrella               | 7       |    |    |
| Acerpenna                | 1       |    |    |
| Anafroptilum             |         | 1  | 2  |
| Anthopotamus             | 1       | 28 | 1  |
| Baetis                   | 8       |    |    |
| Baetisca lacustris       |         |    | 1  |
| Caenis latipennis        | 6       | 68 | 65 |
| Ephemera simulans        |         | *  | 1  |
| Ephemerella invaria      | 23      | 1  | 1  |
| Eurylophella bicolor     | 1       | 11 | 10 |
| Isonychia bicolor        | 21      |    | 1  |
| Leucrocuta               | 1       |    |    |
| Plauditus                | 30      | 1  | 3  |
| Rhithrogena              | 39      | 1  |    |
| Stenacron                | 1       | 1  |    |
| Stenonema                | 4       |    |    |
| Stenonema femoratum      |         | 2  | 4  |
| Stenonema mediopunctatum | 37      | 1  |    |
| Stenonema pulchellum     | 45      | 4  | 3  |
| Stenonema terminatum     |         |    | 1  |
| Teloganopsis deficiens   | 21      |    | 7  |

Bryant Creek, continued.

| ORDER: Taxa              | Habitat |    |    |
|--------------------------|---------|----|----|
|                          | CS      | NF | RM |
| <b>LUMBRICINA</b>        |         |    |    |
| Lumbricina               | 4       |    |    |
| <b>MEGALOPTERA</b>       |         |    |    |
| Corydalus                | 5       |    |    |
| Nigronia serricornis     |         |    | 1  |
| <b>NEOTAENIOGLOSSA</b>   |         |    |    |
| Elimia                   |         | 2  |    |
| Pleurocera               |         |    | 1  |
| <b>ODONATA</b>           |         |    |    |
| Basiaeschna janata       |         |    | 1  |
| Calopteryx               |         |    | *  |
| Dromogomphus             |         |    | *  |
| Enallagma                |         |    | 10 |
| Epitheca (Tetragoneuria) |         |    | *  |
| Hagenius brevistylus     |         |    | *  |
| Macromia                 |         |    | *  |
| <b>PLECOPTERA</b>        |         |    |    |
| Acroneuria               | 1       |    |    |
| Alloperla                | 1       | 1  |    |
| Amphinemura              | 14      |    | 24 |
| Isoperla                 | 3       |    | 1  |
| Perlesta                 | 50      | 2  | 22 |
| Pteronarcys pictetii     | 1       |    | 1  |
| Zealeuctra               | 12      | 2  |    |
| <b>TRICHOPTERA</b>       |         |    |    |
| Cheumatopsyche           | 14      |    | 7  |
| Chimarra                 | 1       |    |    |
| Helicopsyche             | 2       |    |    |
| Hydropsyche morosa grp   | 5       |    |    |
| Nectopsyche              |         |    | 1  |
| Oecetis                  |         | 2  | 1  |
| Polycentropus            |         |    | 4  |
| Protophila               | 3       | 1  |    |
| Pycnopsyche              |         |    | *  |
| Triaenodes               |         |    | 2  |
| <b>TUBIFICIDA</b>        |         |    |    |
| Branchiura sowerbyi      |         | 1  |    |
| Tubificinae              |         | 3  | 3  |